Future Missions and Technologies within ESA's Mars Robotic Exploration Preparation Programme

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European Space Agency

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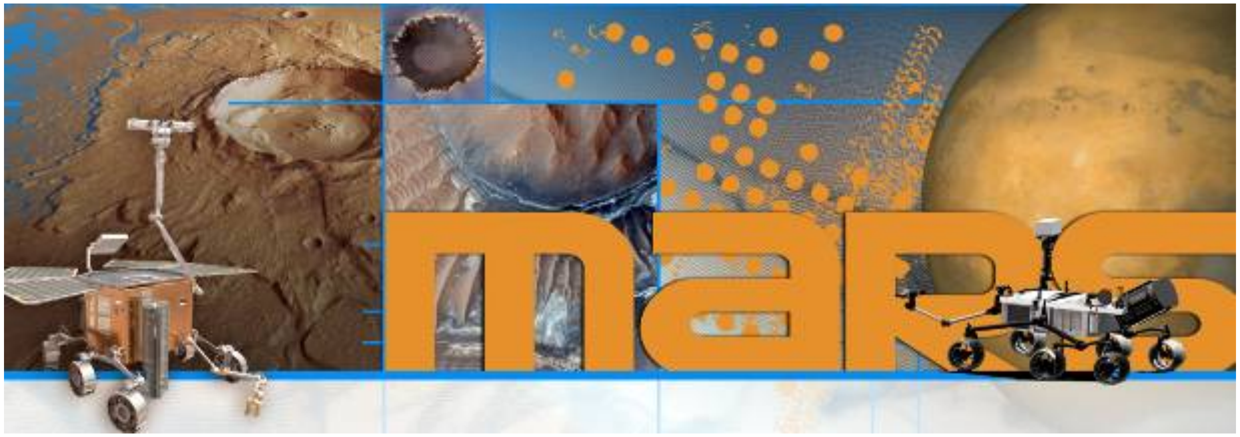


MREP objectives

Mars Robotic Exploration Programme:

- Prepare post-ExoMars missions and enable decisions at next C-Min (2012)
- Target is to contribute to each Mars mission slot (every ~2 years)
- In collaboration with NASA
- Mars Sample Return mission is taken as long term objective

Post ExoMars MREP activities are focused on two main categories:

1. Mission Studies

2. Technology Development

- Short term & Mid Term: post 2018 intermediate mission
- MSR critical Technologies
- Long term: strategic and enabling technologies for European Robotic Exploration

Mission Studies

Following Meetings between ESA & NASA, EMEAC (European Mars Exploration Architecture Committee) & discussion with PB-HME:

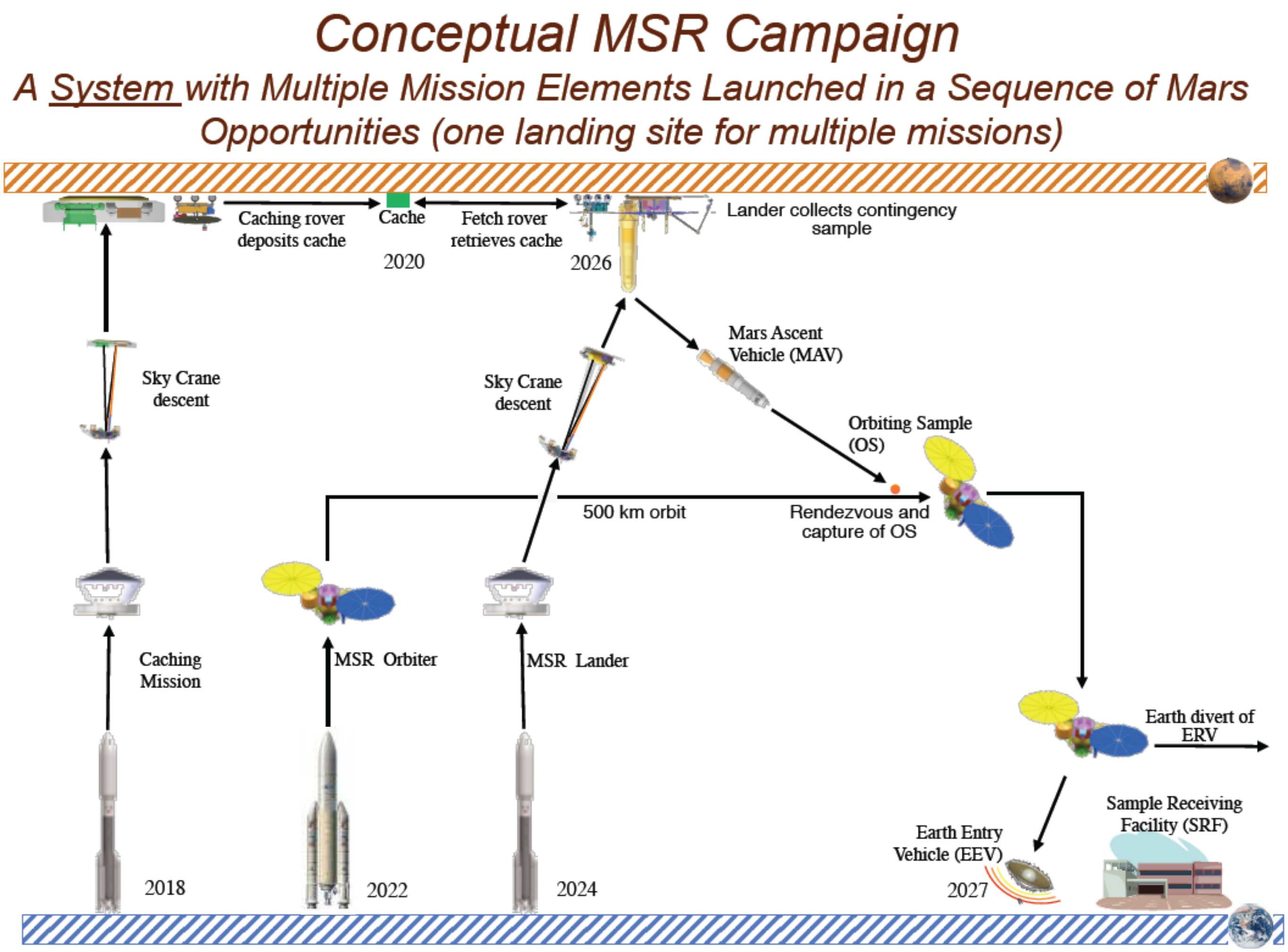
Five alternative missions (following ExoMars(2016/18)) were selected to be studied by ESA in preparation for next C-Min (2012):

1. Network Science mission (2-6 probes), possibly including a high precision landing demo
2. Sample return from a moon of Mars (Deimos or Phobos)
3. Mars atmospheric sample return
4. Precision lander (< ~10 km) with sampling/fetching rover
5. **MSR:** ESA focusing on MSR-orbiter

- 1 to 4: alternatives to cope with potential MSR delays
- 4 & 5: are possible MSR segments under Europe lead
- 4 & 5: studied in 2x2 industrial studies (running)
- 1 & 2: consolidation in Sept/Oct 2011 (2 CDF's)
- 3: CDF already done in Aug/Sep 2010

⇨ **Down-selection by the next C-Min(2012) to 2-3 candidate missions**

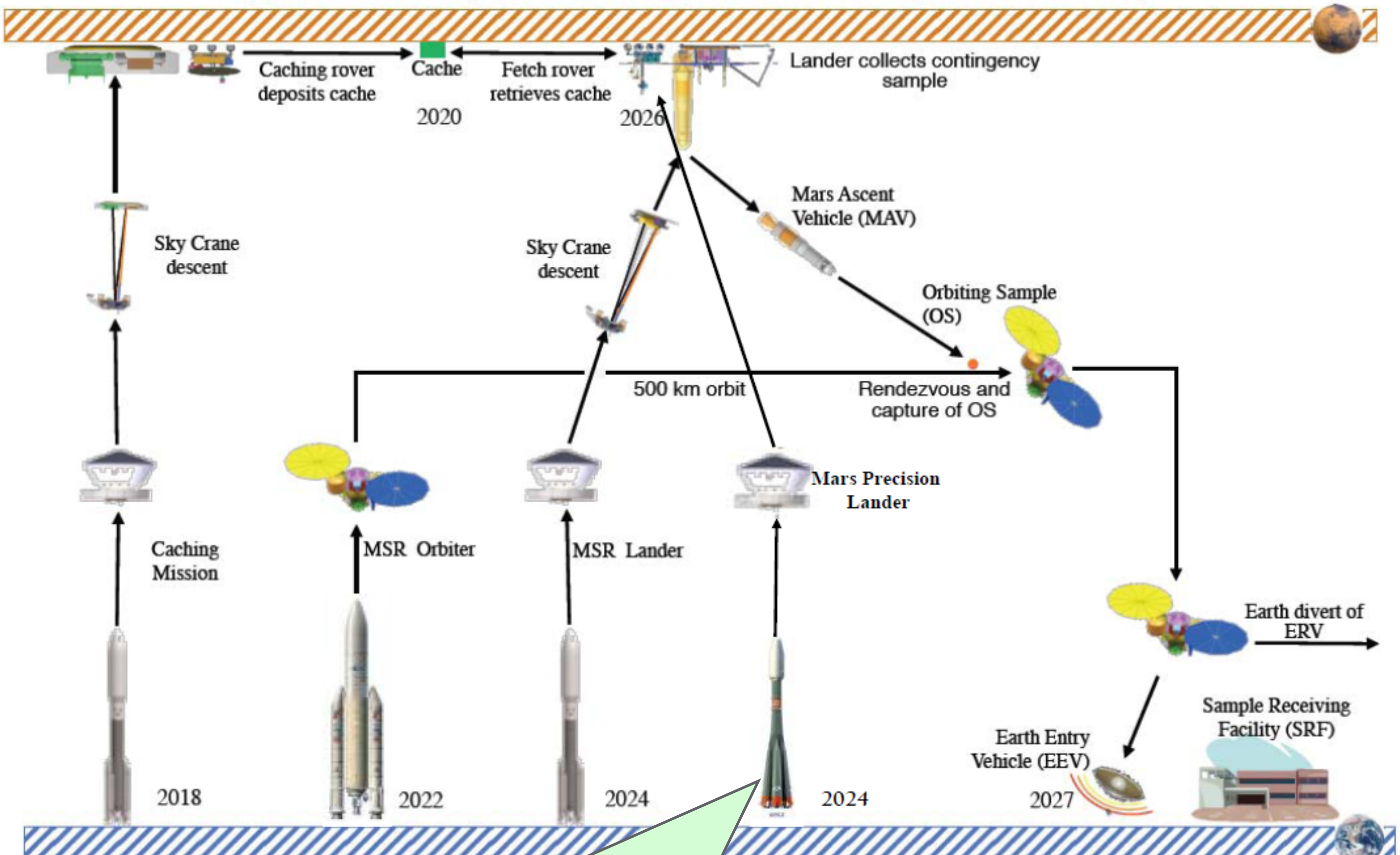
Current MSR Mission Concept



Alternative MSR Mission

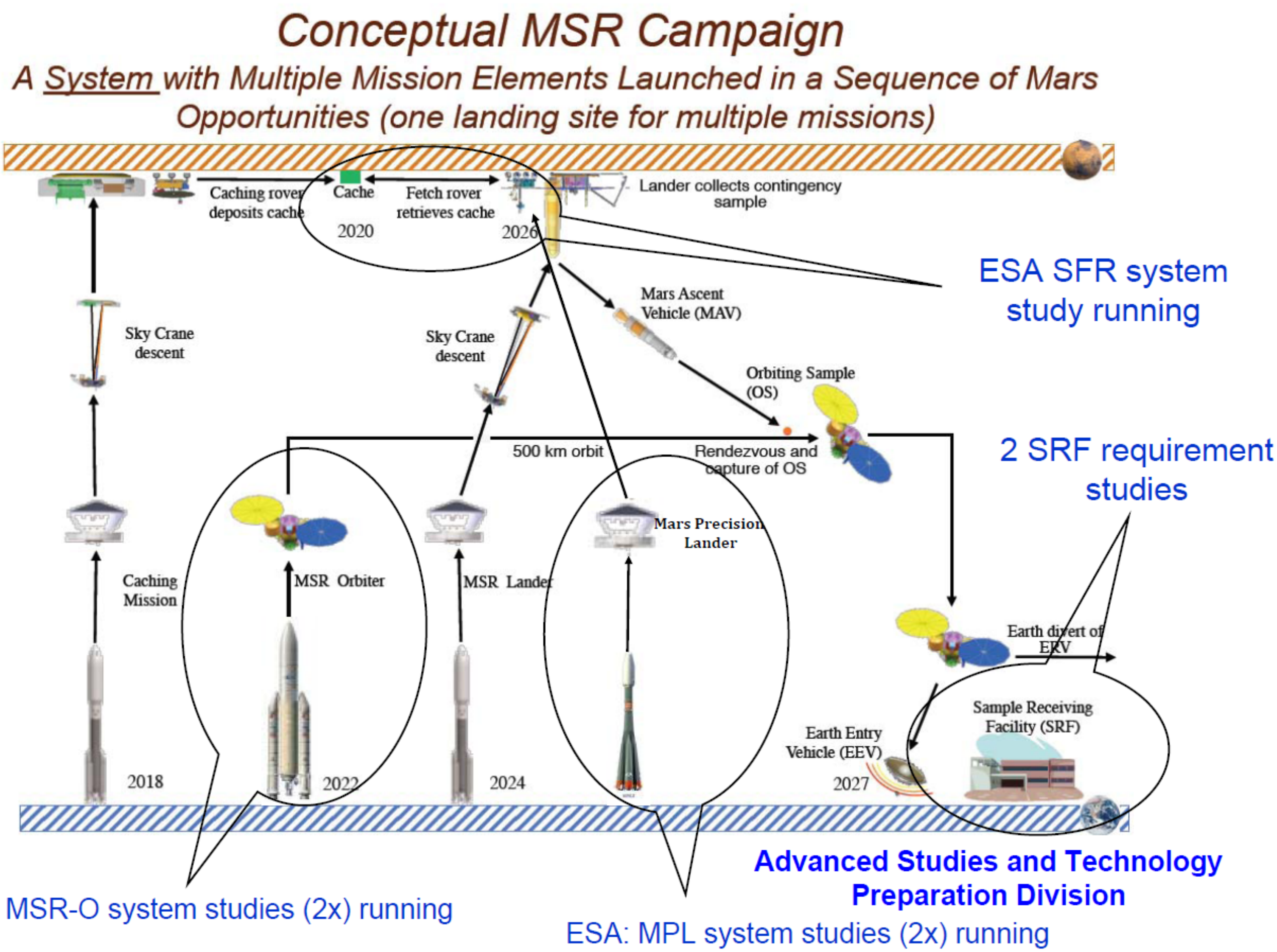
Conceptual MSR Campaign

A System with Multiple Mission Elements Launched in a Sequence of Mars Opportunities (one landing site for multiple missions)



Additional Element in case of mass limitations for 2024 MSR Lander

Current MSR Mission Overview



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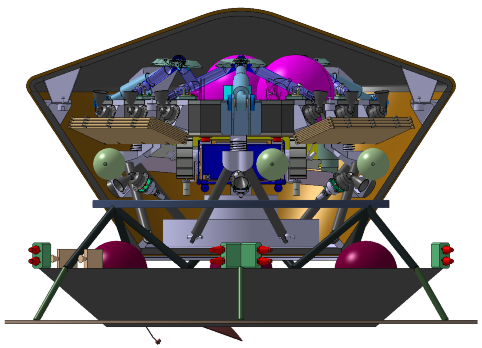
Mars Precision Lander

The mission main objective is to land a rover of 85 kg class (optionally scaled up to 300 kg) on the Mars surface, with precision landing (<10 km) and possibly hazard avoidance.

Mission Scenario:

1. Launch on Soyuz Fregat-2b
2. Transfer to Mars (direct or via GTO)
3. Hyperbolic release, guided entry, descent and landing
4. Deployment of surface element

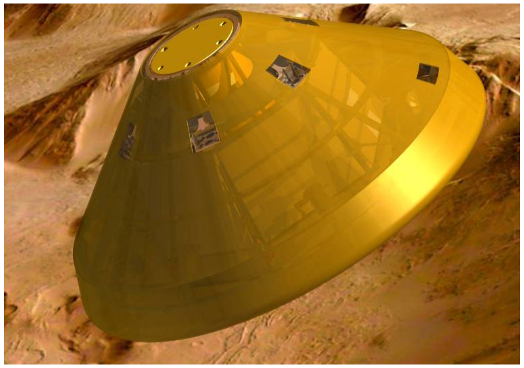


Rationale:

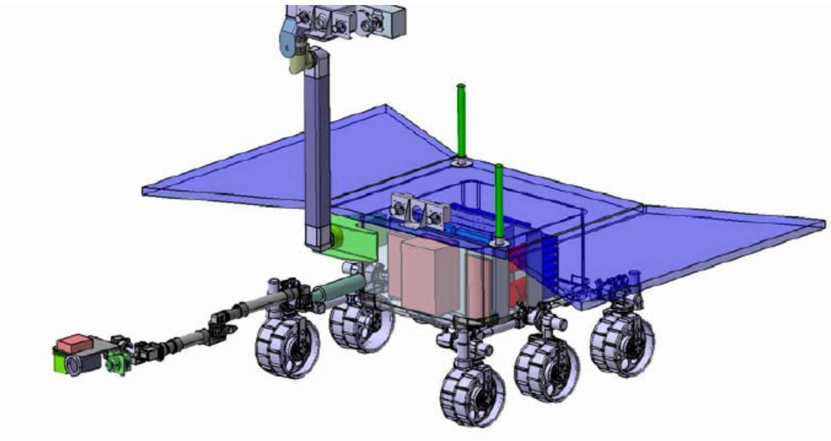
- Possible added element to MSR (in particular in case the fetching rover and the MAV cannot be landed together due to mass restrictions)
- Backup stand alone mission in case MSR is delayed

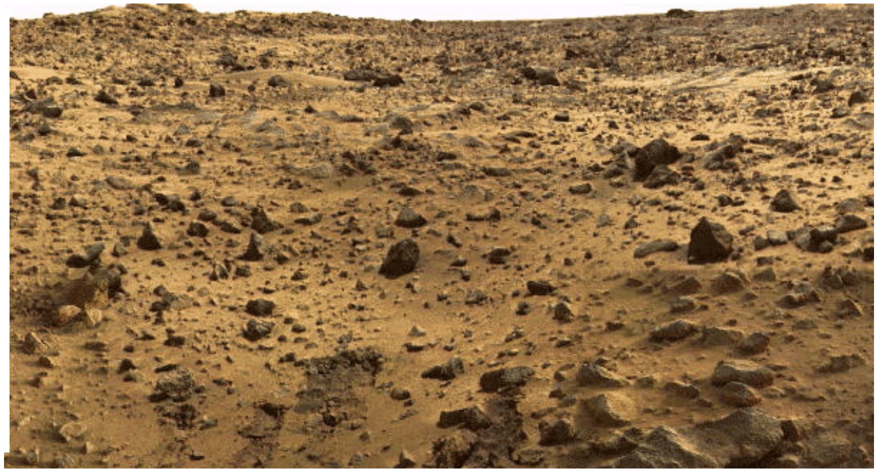
On-going activities on precision lander:

- Two Industrial system assessment studies are running
- Several technology development activities on EDL & GNC including precision landing and hazard avoidance in MREP/ETP
    a. Improved navigation prior to Mars atmospheric entry
    b. Guided entry to compensate known dispersions at entry and minimise errors introduced by atmospheric uncertainty
    c. Smart parachute deployment triggers
    d. Hazard avoidance system: lidar and/or camera-based
    e. Different landing systems such as legs and airbags

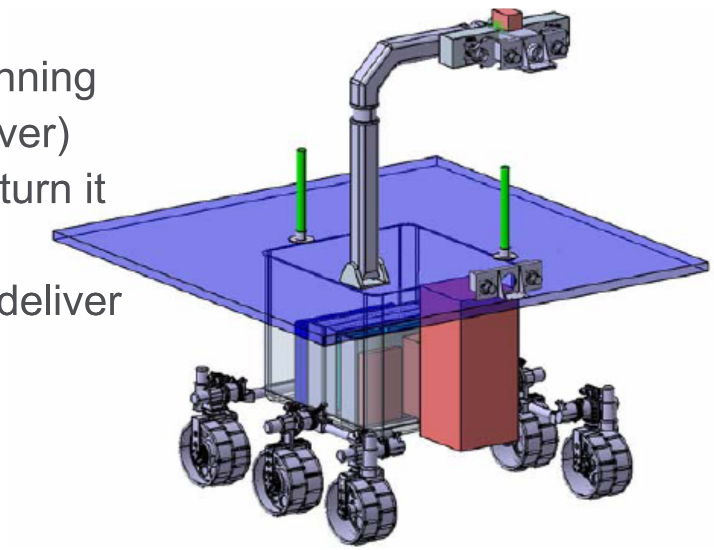


Sample Fetching Rover





- 2 industrial system assessment studies contracts are running
- Light weight and highly mobile rover platform (~85 kg rover)
- Baseline scenario (MAV element): retrieve cache and return it to MAV
- Alternative scenario (MPL element): retrieve cache and deliver it to MAV element
- Both scenarios minimum 15 km transverse required
- mission timeline ~180 sols
- requires > 120 m/sol



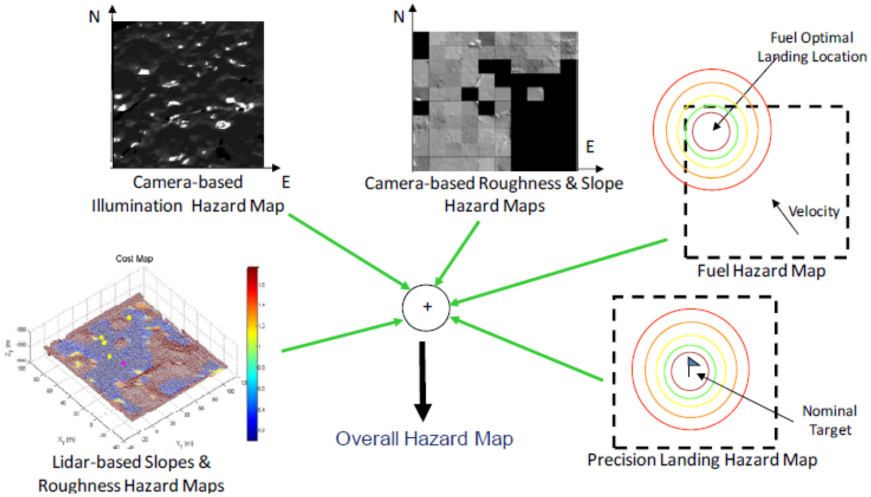
Precision Landing Technologies (1/2)

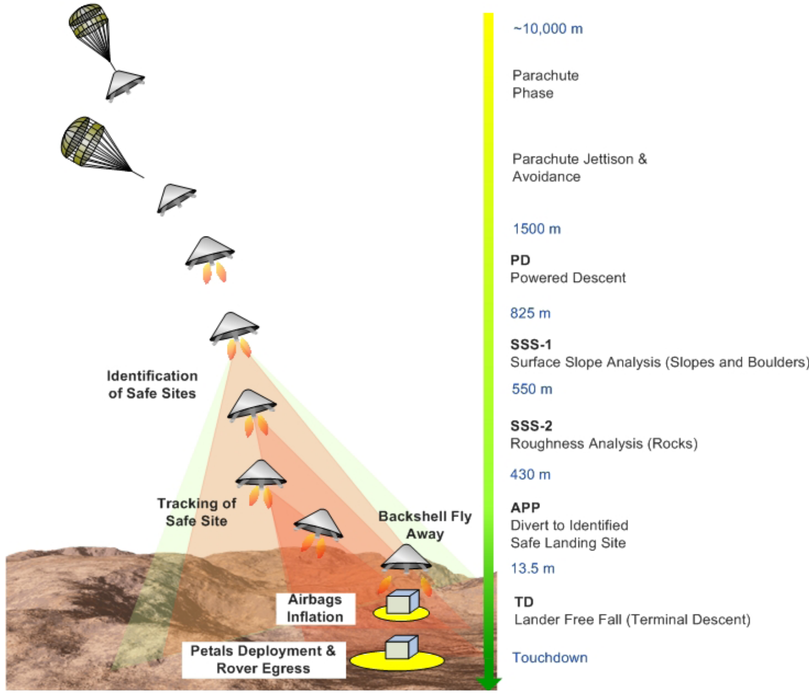
- **End to end optimisation and GNC for precision landing:**
  - Objective: optimise and design complete GNC chain for precision lander, establish high fidelity simulator and implement on flight like processors
  - Based on several precursor activities considering guided entry
  - Status: kick off imminent
- **Camera aided Mars landing:**
  - Objective: to assess impact of specific Martian and landing environment impact on vision based navigation
  - Status: kick off in September 2011 – 2 contracts
- **Sensors:**
  - Lidar: landing lidar developments ongoing (both flash and scanning lidar)
  - Accelerometer and IMU: Accelerometer design and breadboarding ongoing. Follow on activity for the accelerometer and IMU development study proposed for 2012 (to be approved).
  - “Assessment and breadboarding of Planetary altimeter”: Kick off in Q3 2011
- **Throttleable engine:**
  - Throttleable valve development ongoing
  - To be integrated in monopropellant engine in a follow up activity

Precision Landing Technologies (2/2)

Hazard avoidance

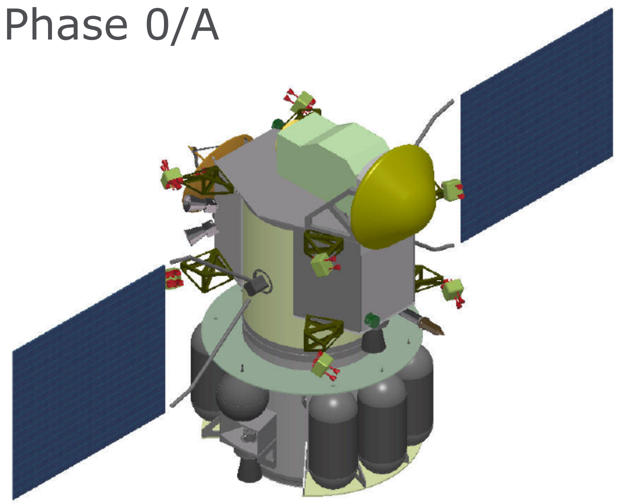
- Hazard mapping
  - Both vision and lidar based hazard (rocks, slopes, illumination, roughness) mapping being studied
  - Vision based hazard avoidance being tested on helicopter
  - Lidar being developed for lunar lander
  - MREP 2011: sensor data fusion
- Site Selection
  - IPSIS: Intelligent Planetary Site Selection using non exhaustive approach with use of historical information
- Piloting
  - Part of ongoing end to end GNC design activities and simulators

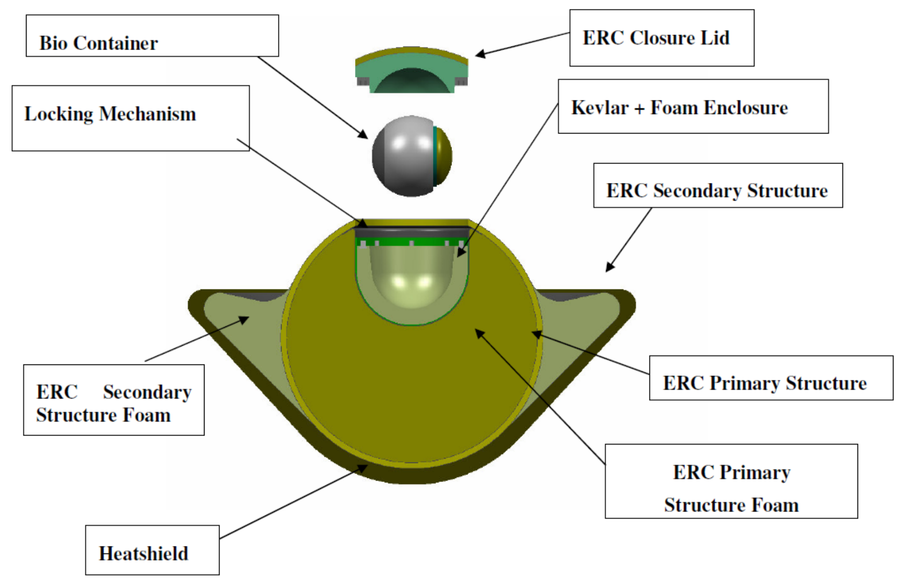




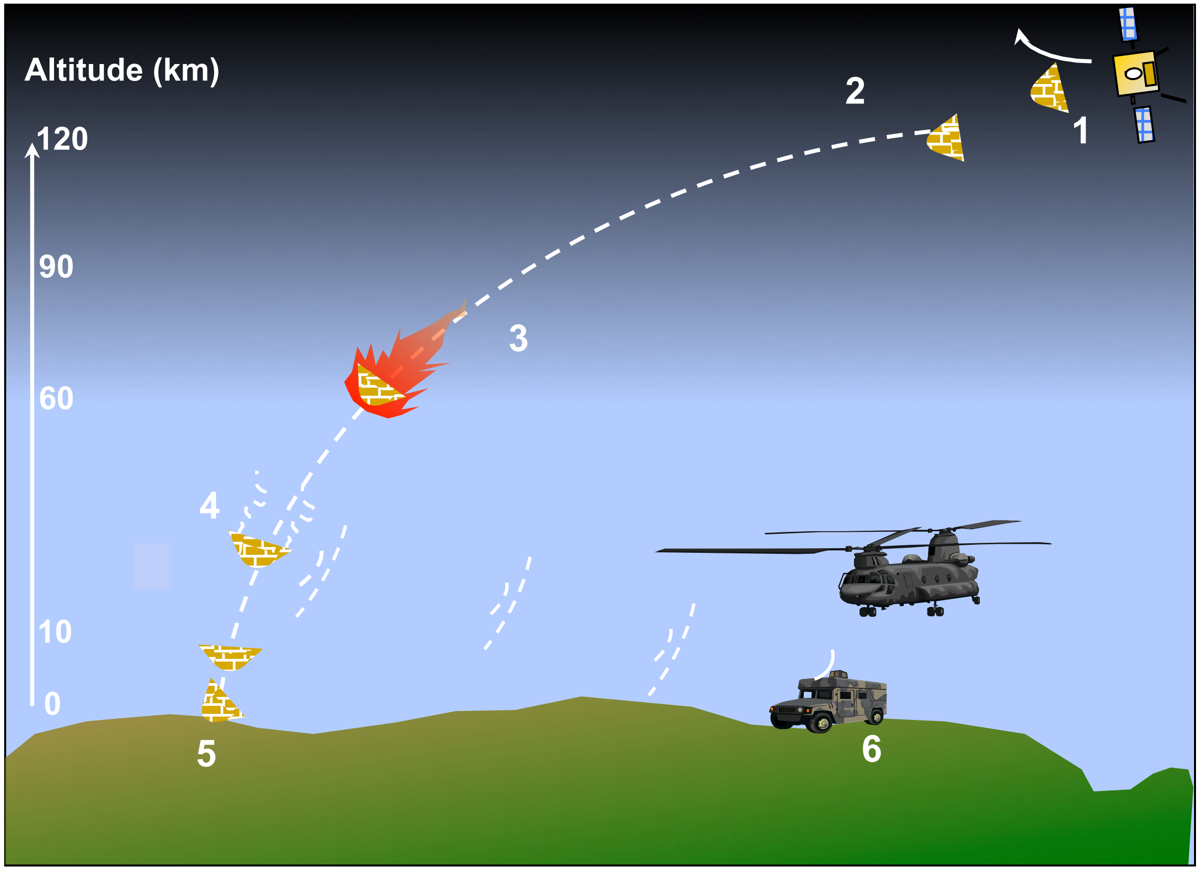
Mars Sample Return Obiter/ERC

- Two ongoing industrial system studies – Phase 0/A
- Four main innovative capabilities:
  - Rendezvous and capture
  - Bio-containment
  - High speed Earth re-entry
  - Sample receiving facility
- Earth re-entry capsule:
  - 12.3 km/s re-entry velocity
  - 45º half-cone angle
  - ~ 90 Kg
  - Max. heat flux ~ 15 MW/m^2 at 1 bar dynamic pressure
  - Impact velocity: ~ 40 m/s
  - Max. landing loads 400 g



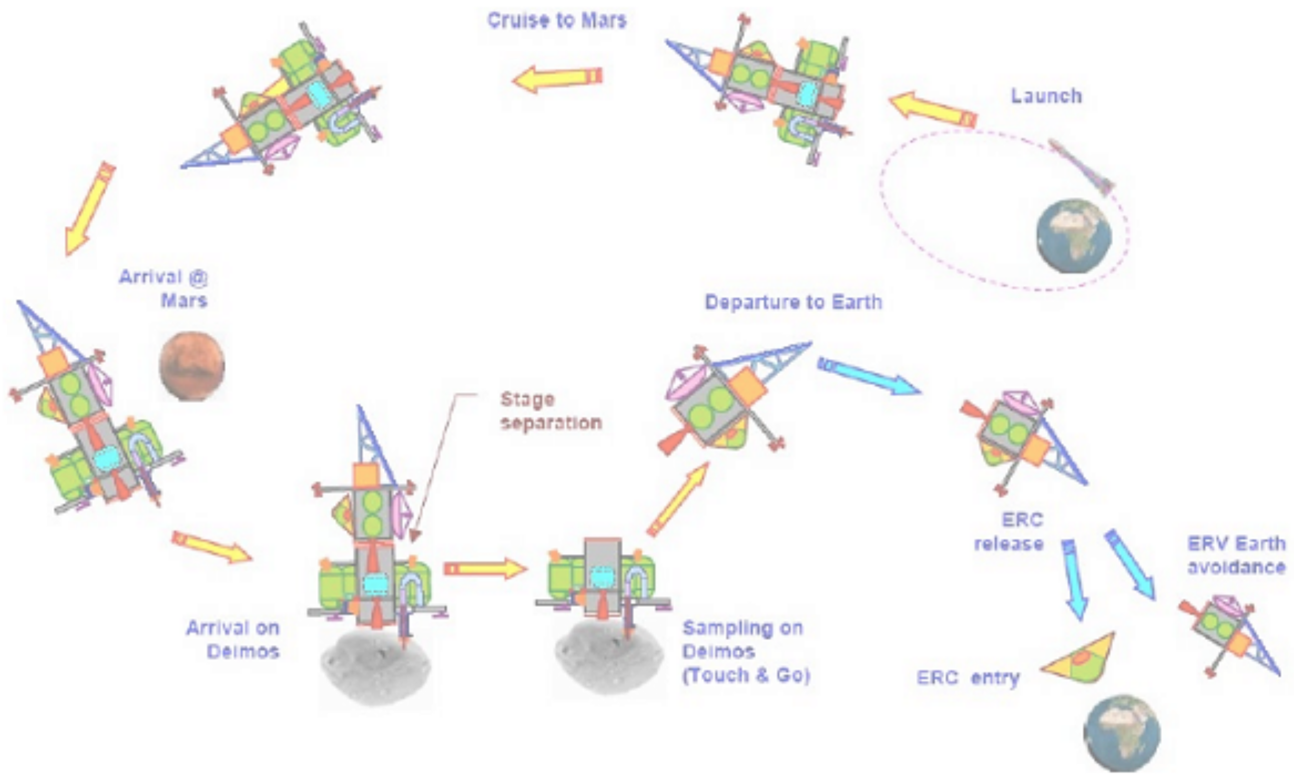


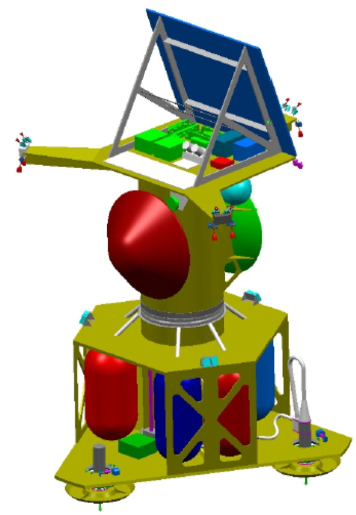
Mars Sample Return – ERC re-entry phase



1. T_0 – few days: Separation with main spacecraft
2. T_0: Re-entry
3. Peak heat flux ~ 15 $MW.m^{-2}$
4. Passage through transonic
5. T_0 + 500 s: Hard landing
6. Landing + few min/hrs: Search & Recovery

Deimos or Phobos Sample Return

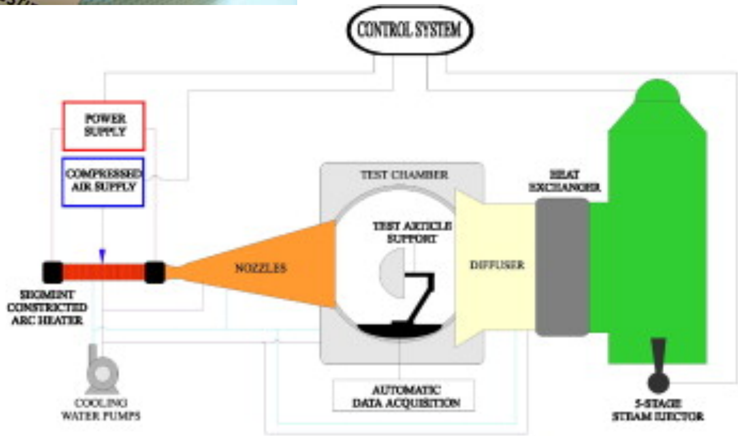




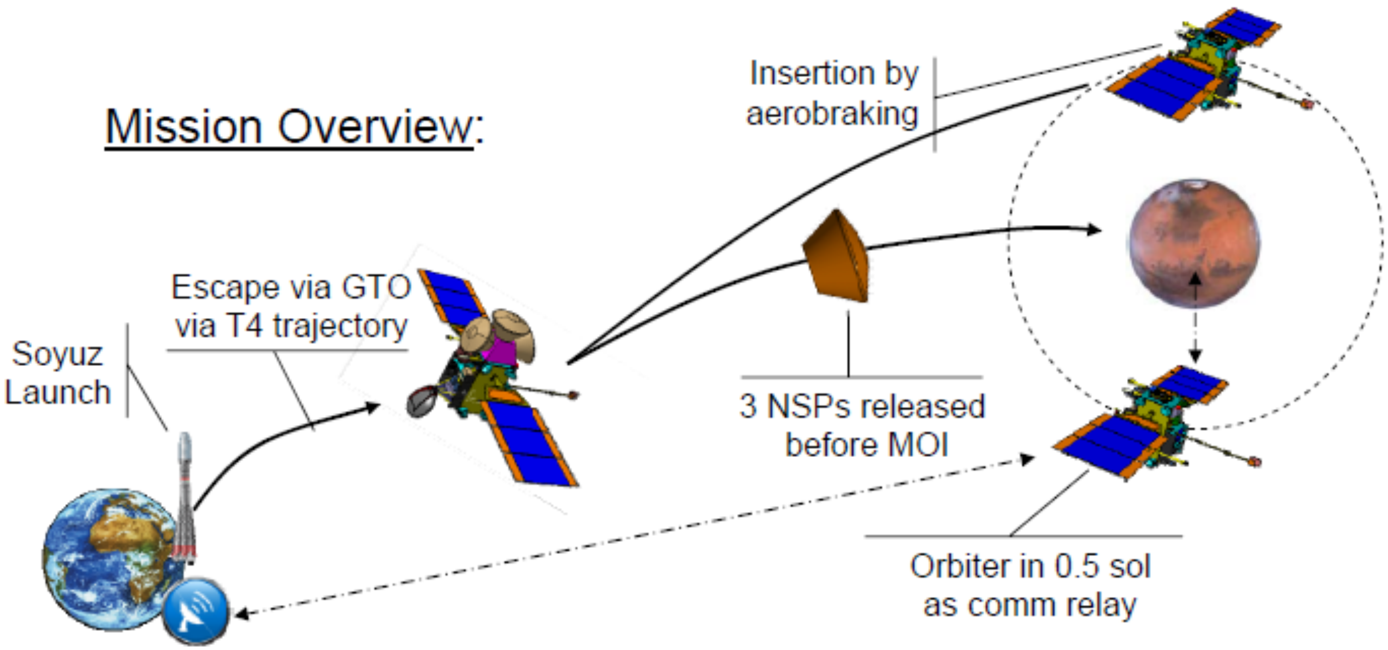
- Similar chain as for MSR, but no Mars Ascent Vehicle required
- Earth Re-entry environment similar to MSR
- But restricted return might not be required (to be confirmed). Yet, re-entry capsule may also use passive re-entry to demonstrate the capability for MSR
- Capsule design similar but lighter if no bio-container is required
- Backup standalone mission in case MSR is delayed

Earth re-entry vehicle technologies

- TPS material
  - Ongoing trade-off for two materials
  - Follow-on activity to pre-qualify the selected candidate
  - Low or high-density (e.g. carbon phenolic)
  - Very stringent reliability issues to be taken into account for MSR
- Test facilities
  - Shock-tube for radiations
  - Upgrade of facilities to reach higher heat fluxes at the right dynamic pressure
- Shock-absorbing material
  - Candidates: Titanium hollow sphere, carbon foam, etc.



Network Science Mission



The mission main objective is to land a number of surface static probes of 150-kg class on the Mars surface, to perform geodesy and environmental science.

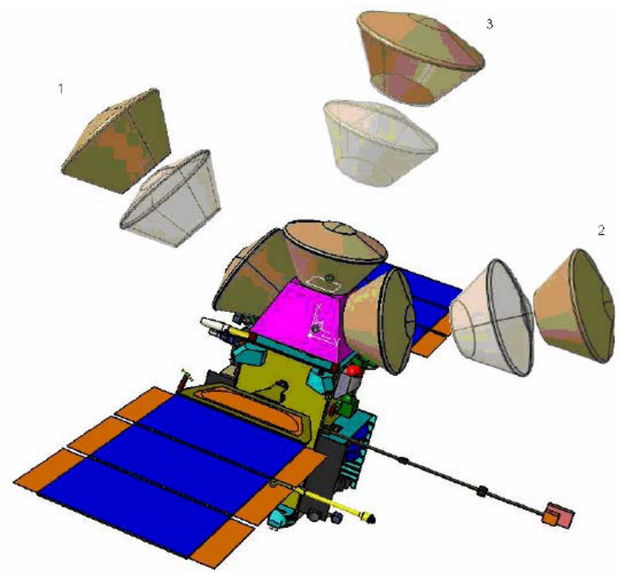
- Could be done without orbiter = mission simplification
- Mission considered with Soyuz or Ariane 5
- Backup stand alone mission in case MSR is delayed

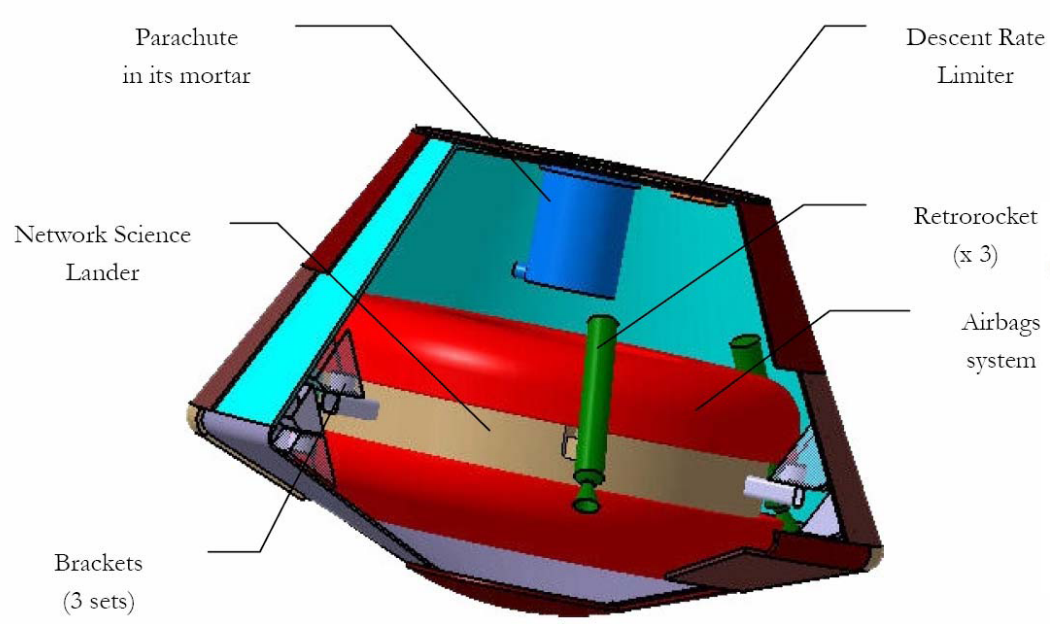
Network Science Mission - EDL

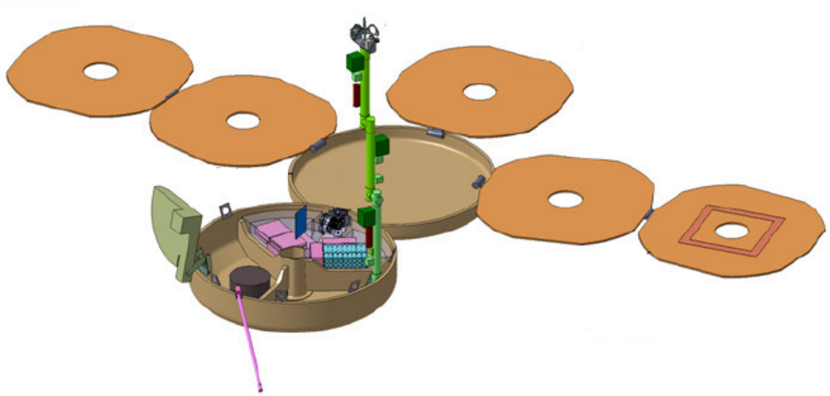
- 2 EDL strategies are looked at
- Example:
  1. Entry
  2. Descent: parachute activated at relevant Mach number
  3. Front shield jettison
  4. Lowering of the lander
  5. Airbag inflation
  6. Altitude-triggered retro-rockets
  7. Bridle cut, back cover drifts away
  8. Probe free-fall
  9. Bouncing
  10. Resting position, end of EDL sequence
  11. Airbag removal (deflation or separation)
  12. Probe deployment

Network Science Mission – Probe design

1. 5.7 km/s entry velocity
2. 130 kg for Soyuz, 170 kg for A5
3. 70º half-cone angle
4. Max. heat flux ~ 1 MW/m^2
5. Norcoat Liege (Beagle 2, ExoMars)







Network Science Mission – Technology

- Landing system
  - Breadboarding of airbag for small landers
- Aerobraking demonstrator
- Planetary altimeter for EDL GNC
- Subsonic parachute testing

- EDL system optimization:
  - 2 parachutes with bouncing airbags, no retro-rockets - 1 parachute, retro-rockets and airbags
  - Need for lateral control versus more robust airbags

Summary

- The European Mars robotic exploration preparation programme is widely and strongly supported by the participating Member States
- Mars Sample Return is taken as the long-term objective
- MSR will be an international endeavour
- Intermediate missions can fly either as a complement to MSR or as an alternative in case of delays, whether they result from programmatics or technical issues
- These intermediate missions can not only bring outstanding science value to the programme, but can also be used as technology demonstration platforms for MSR or other future Mars missions

END

MREP technology plan on the web:
http://iue.esa.int/science-e/www/object/index.cfm?fobjectid=47729#